Interactions Among Behavioral Responses of Baleen Whales to Acoustic Stimuli, Oceanographic Features, and Prey Availability

Dr. Ari Friedlander
9099 Soquel Drive, Suite A
Aptos CA 95003
phone: (831) 661-5177 fax: (831-661-5178 email: asf7@duke.edu

Award Number: N00014-11-1-0698
http:// www.sea-inc.net

LONG-TERM GOALS

The long term goals of our research are two-fold. We aim to first determine how the distribution, abundance, and behavior of prey affects the foraging behavior and ecology of baleen whales in the waters off the California coast. Baleen whales employ a variety of feeding strategies that relate to the behavior of their prey and understanding these is paramount to being able to assess changes in their feeding ecology. Second, we will use this information on how prey affect whale behavior to better understand the potential behavioral responses of baleen whales to controlled exposure experiments. One of the most fundamental changes measured during this experiment is behavior. In order to determine whether or not behavioral changes occurring in baleen whales during controlled exposure experiments are due to the input of sound into their environment, we need to better understand and quanitfy if there are changes in their prey environment that can account for the behavioral change as well. In baleen whales, the behavioral states most commonly observered are feeding, traveling, resting, and socializing. During summer months off California, the majority of whale behavior is foraging, and therefore understanding how changes in their prey affect the likelihood of changing behavioral states is necessary to be able to detemrine the true affects of anthropogenic sound on these animals.

OBJECTIVES

The current project obtained basic distribution and density information for prey concurrent with foraging mysticete cetaceans during behavioral response studies. This information on prey will be used to provide insight regarding the movement patterns and foraging behaviors of the whales and will help to elucidate how changes in whale behavior can be accounted for by changes in the distribution and abundance of their prey and/or by the presence of human sounds.

APPROACH

The specialized SIMRAD EK60 echosounder units (38 and 120 kHz echosounders and GPTs) and top-side hardware were made available for the project through collaborations with research partners at Duke University (Dr. Doug Nowacek). A specialized echosounder mount and towfish appropriate for the SOCAL-BRS platform was fabricated with support from this award. The two Echosounder units

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **30 SEP 2011**	2. REPORT TYPE	3. DATES COVERED **00-00-2011 to 00-00-2011**

4. TITLE AND SUBTITLE **Interactions Among Behavioral Responses of Baleen Whales to Acoustic Stimuli, Oceanographic Features, and Prey Availability**	5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Southall Environmental Associates, Inc,9099 Soquel Drive, Suite A,Aptos,CA,95003**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S) 11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**8**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

are shown mounted on the towfish in the figure (Figure 1). The smaller orange echosounder operates at 120 kHz and the larger echosounder operates at 38 kHz.

Figure 1. The two echosounder units mounted on the towfish.

Several computers were required, including a ruggedized laptop computer specific to data acquisition (Dell Latitude E6420 ATG) and a laptop computer for field/lab data analysis (MacBook Pro - 15.4/2.3/2X2GB/750/SD/HR-AG). Additionally, several external data storage drives and other ancillary gear (e.g., handheld GPS unit) were required and obtained with this award. The information from each echosounder is processed in a GPT (general purpose transceiver) that also acts as a power supply. The data are then streamed through Ethernet cables to the laptop where they are processed in customized visualization and analysis software (Echoview), also on loan from Duke University. The data are stored directly on the laptop computer and backed up on external hard drives routinely. A hand-held Garmin GPS unit is connected to the laptop to provide a time and location stamp for the echosounder data as it is acquired.

Finally, a plankton sampling system was obtained for the second leg of the project, given the interesting measurements made initially and the inability to obtain plankton species identifications. This consisted of a triple-stitched plankton net (100 cm X 500 cm X 1000 Microns x 11 cm diam; 4.5”0 COD end aperature), an SS-ring and bridle assembly, a complete 2-PC PVC COD end assembly (1000 microns), and a mechanical flow-meter. This net assembly is shown being deployed from the back of the SOCAL-BRS research vessel (Figure 2). In order to quantify the density and biomass of prey measured from the echosounders it is paramount to generate length-frequency estimates of the actual targets that are being measured. Thus, incorporating the net into our sampling protocols will allow for more accurate and quantitative estimates of prey for our analysis.

Figure 2. The net assembly being deployed from the back of the SOCAL-BRS research vessel.

Fine-scale prey density and distribution and individual predator behavior was measured in two phases (late-July to mid-August and September 2011) using the existing research platform (R/V Truth). By analyzing prey and predator at fine scales (100s of meters), we can begin to test for the relationships between prey distribution and predator behavior and understand the ecological decisions made by individual whales when foraging, and how the broader oceanographic environment affects blue whales in southern California.

<u>Prey sampling</u> - Prey distribution and abundance were continuously measured using 38 and 120 kHz SIMRAD EK60 echosounders at fine scales (<10 km). Acoustic data collected in the absence of sighted or tagged whales were treated as a control measure of ambient prey density. Fine scale sampling methods were dependent on the behavior of the tagged whale so an iterative approach to sampling prey was employed. If the tagged whale was traveling (>1km per hour displacement), a zig-zag design was used to survey prey distributions passed over by the whale by sampling in its wake (~1.4km long transects). When focal whales were surface feeding (defined as observing the animal with its mouth gaped) or stationary deep feeding (repeated surfacings in a compact area), a clover leaf sampling design allowed the measurement of prey abundance and distribution, with the center of the clover centered around the whale (Figure 3). The sampling design around non-feeding and non-traveling (i.e. resting) individuals is identical, with a cloverleaf used to examine the prey distribution in the absence of feeding. When measuring prey relative to surfacing events, transects were designed to pass within 200 meters of the tagged whale. Correlations between whale behavior, prey data, and environmental data, will only be considered in analysis within a 500m radius of a whale surfacing. This will allow us to quantify the distribution, abundance and dimensions of prey patches in close proximity to foraging and non-foraging whales. We will also compare the two frequencies of acoustic data to differentiate krill from larger fish targets as krill have greater backscatter at 120kHz than 38kHz.

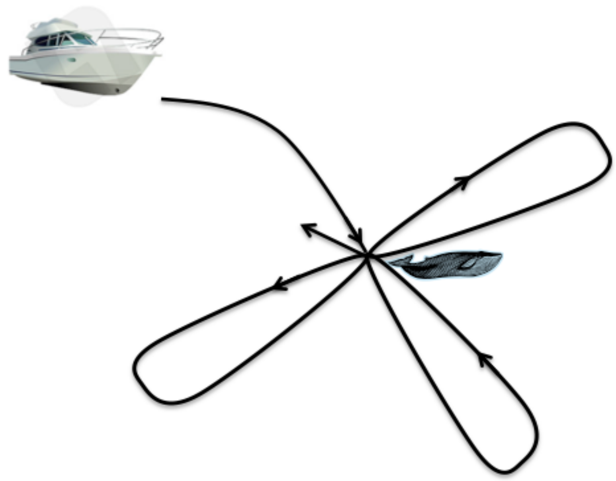

Figure 3. Clover leaf sampling design around tagged whale. Each leaf is 1km from the center.

<u>Whale data</u> - Whale behavior (e.g., feeding/non-feeding) is inferred from the tag record in combination with near continuous daytime focal surface observations. Tags were attached from rigid-hulled inflatable boats (RHIB) by taggers using hand-held poles from which WHOI DTags were deployed. The Dtag is a small, lightweight, pressure tolerant tag capable of recording data for up to ~20 hours and attached to the whale non-invasively via suction cups. The Dtag measures the acceleration in the animal's pitch, roll, and heading, as well as depth, and water temperature at 50 Hz. The tags also measure sound and calibrations have been made between vertical acceleration and flow noise to determine when whales lunge underwater. This is determined by increased acceleration as the whale approaches a prey patch and dramatic deceleration when the animal opens it mouth to lunge and engulf prey. This approach has been published and ground-truthed for several species of baleen whales, including blue whales and thus is considered the most accurate way of determining feeding events in baleen whales from tag-derived records. Data from the pitch record also allows for analysis of fluke stroke rates and relative stroke amplitudes and combined with behavioral observation allows the identification of surface feeding bouts and quantification of their duration. All sensor data are stored in flash memory on the tag and are downloaded via an infrared connection to a computer for analysis. The tag has a VHF antenna which transmits when at the surface, allowing us to follow the whale when it is either out of visual range or during nighttime. Focal follows were conducted from RHIBs such that animal's position was recorded by marking a GPS position at the location (foot-print) and time where the tagged whale made a terminal dive. Additionally, we augmented this method by collecting high-resolution range and bearing measurements using a laser range-finder (Leica Vector IV), to georeference the surfacing locations of the tagged whale more frequently. Similar to previous studies using non-linear generalized additive models, in analysis we will quantify the effects of remotely sensed environmental features and prey abundance on the distribution and abundance of whales at the seascape scale. This approach will provide estimates of (1) prey and environment in the functional study area around blue whales and (2) the functional relationships between prey density and school size and predator aggregation size.

WORK COMPLETED

Fine-scale prey density and distribution and individual predator behavior was measured in two phases (late-July to mid-August and September 2011) using the existing research platform (R/V Truth). Acoustic data were obtained over a total of 11 days during the SOCAL-11 project. Eight of these sampling days occurred in prey patches within which tagged whales were present, four of which included measurements obtained around the same tagged whale(s) before and after sound exposures in controlled exposure experiments. Most of these sampling periods occurring during the first phase when prey patches were more commonly present and aggregations of whales were predictably greater as well. In addition to some differences in oceanographic and animal distribution conditions, favorable offshore weather conditions during the second leg of SOCAL-11 meant that more focus was placed on working with more pelagic odontocete species rather than coastal baleen whales. Unfortunately, the limited chances to focus on prey mapping and prey sampling in the second leg when the plankton net was available meant that relatively few deployments and actual prey samples were obtained.

RESULTS

The distribution and constitution of krill patches throughout the study area was highly variable indicating that blue whales need to be plastic in their foraging strategies. The combined active acoustic and tag data, along with the georeferenced positions possible from the focal follows, will provide detailed insight into the foraging strategies and foraging ecology of individual blue whales in southern California that heretofore could not be conducted or quantified in as comprehensive a manner. Additionally, these data will be particularly useful in assessing behavioral responses (or lack thereof) for those CEEs during which prey sampling measurements were obtained.

Several examples of krill aggregations associated with a shelf break

Krill were commonly associated with bathymetric gradient. The top panel in each figure shows backscatter from the 120 kHz transducer and the bottom panel from the 38 kHz transducer (Figures 4-8). Red and yellow colors indicate higher backscatter levels.

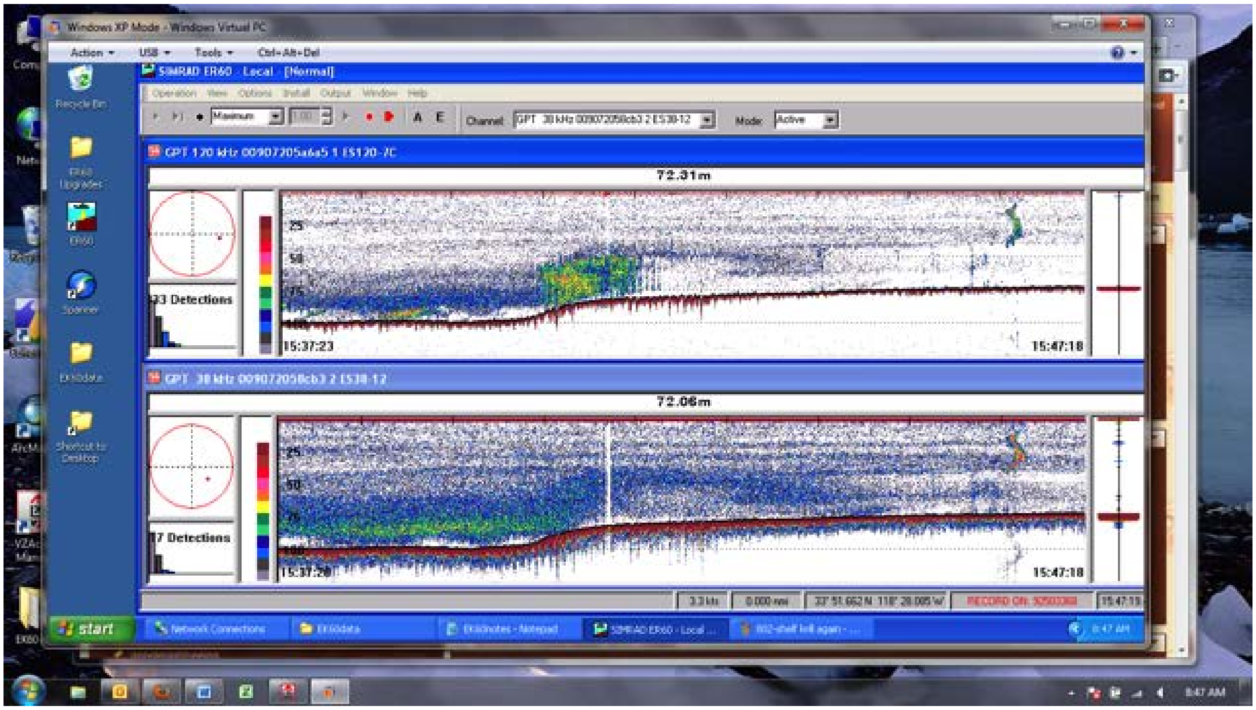

Figure 4. Isolated krill aggregation associated with the ocean floor

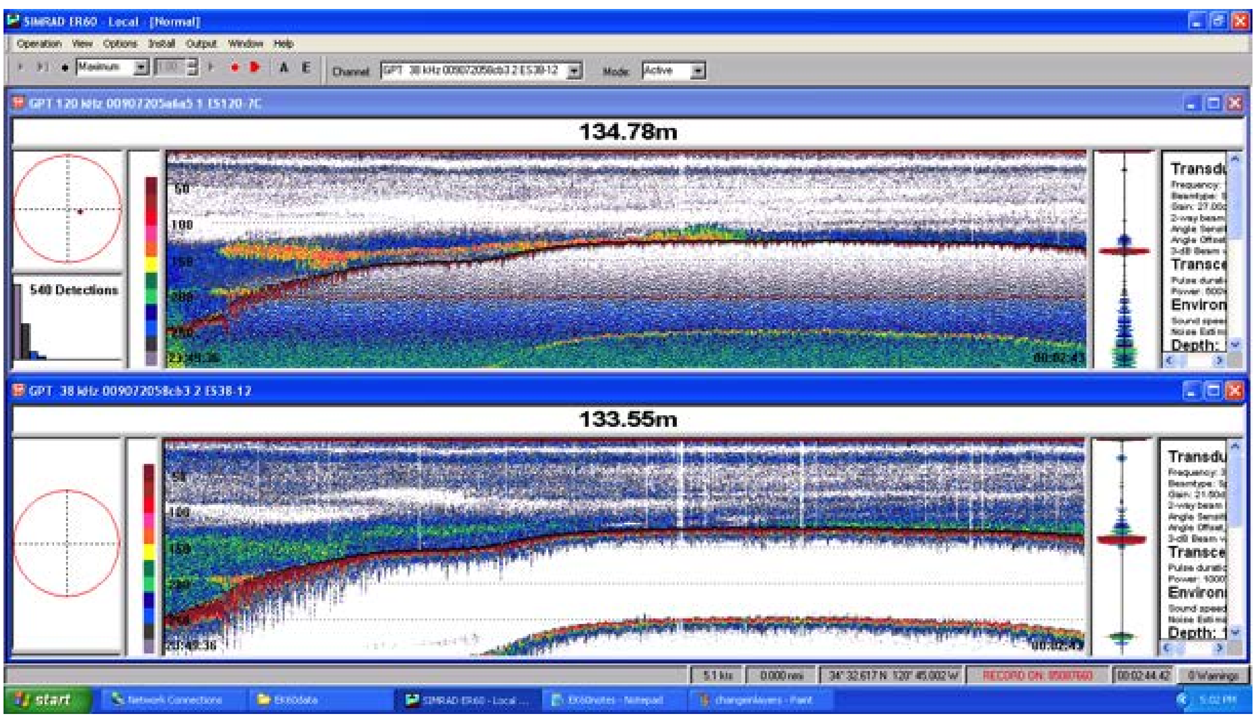

Figure 5. Isolated krill aggregation associated with the ocean floor

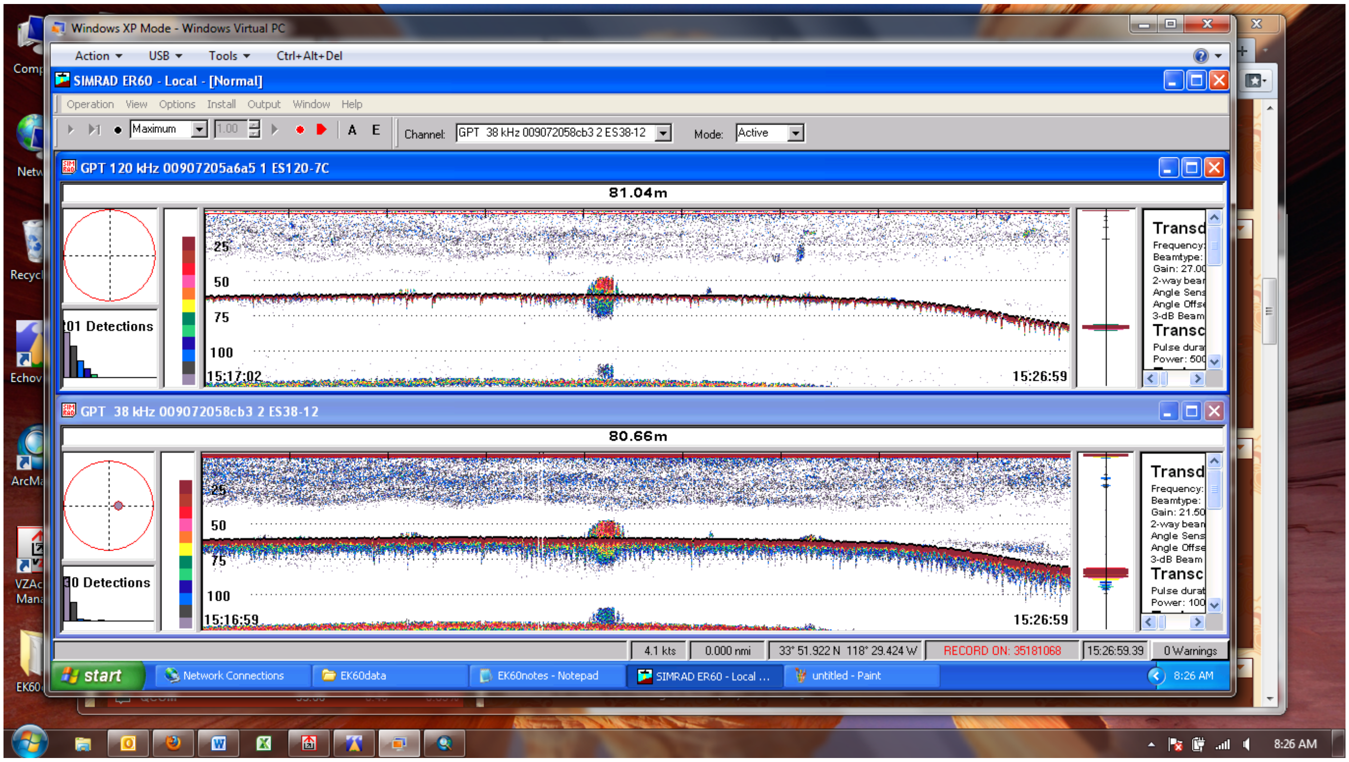

Figure 6. Shallower midwater krill patches

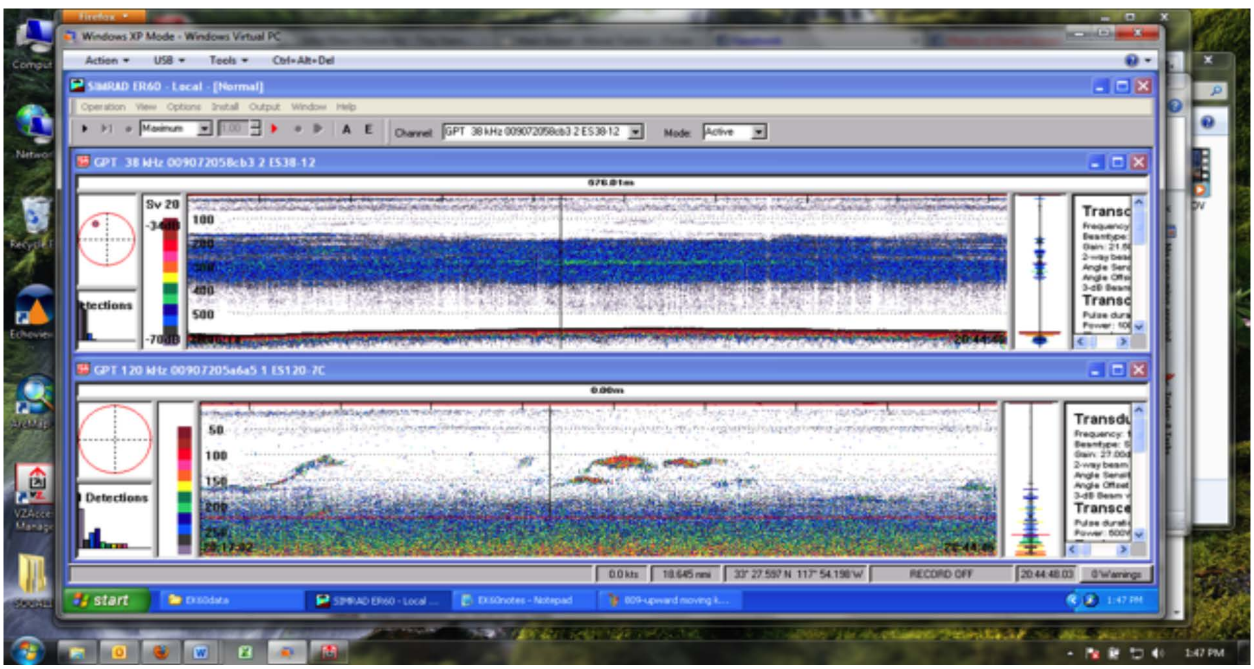

Figure 7. Dense aggregation from ocean floor to near surface

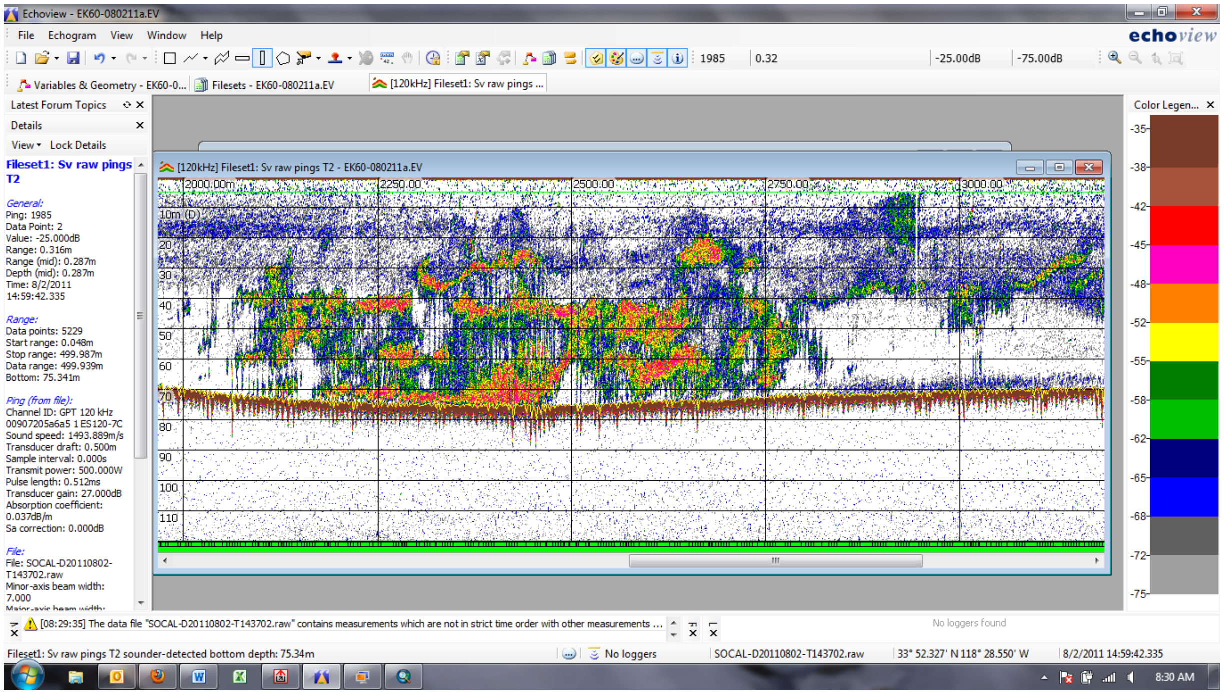

Figure 8. Dense krill aggregations at surface and near bottom (in presence of lunge-feeding whales)

IMPACT/APPLICATIONS

This work will greatly impact researchers studying the ecology of marine mammals. We will be able to significantly contribute to the current state of knowledge regarding the foraging ecology and feeding behavior of baleen whales. We will be able to determine how changes in prey affect how baleen whales feed. This is useful for understanding how changes in the marine ecosystem will likely manifest in the distribution, movement and feeding patterns of whales. Additionally, we will be able to contribute significantly to our understanding of if and how anthropogenic sounds affect baleen whale feeding. We will be able to determine if there are particular feeding strategies of prey patch dynamics that whales will abandon or change their behavior in repsonse to anthropogenic sound input and apply this understanding to other locations and marine ecosystems.